Mechelectiv

Volume 23 March - 1965 No. 4

Introducing

THE "PLAYBOY ENGINEER"

THE GEORGE WASHINGTON UNIVERSITY

MARCH 1965

Atomic rocket reactor successfully test fired by Westinghouse

Atomic rocket power will permit round trips to Mars, Venus and beyond

With atomic power, it is possible for rockets to carry bigger loads farther than with conventional fuels. The first full power test of the reactor for NERVA (Nuclear Engine for Rocket Vehicle Application) promises a new United States capability for voyages into deep space and to the planets.

Westinghouse designed and built the NERVA reactor. NERVA is part of the Rover Program under the management of the AEC-NASA Space Nuclear Propulsion Office. Westinghouse is the world leader in developing atomic reactors for many applications, including atomic electric generating stations.

You can be sure if it's Westinghouse

B-52. 8-engine jet bomber with range of over 9000 miles. Backbone of the Strategic Air Command.

Are you ready for a multi-million-dollar responsibility?

If you are, there's a place for you on the Aerospace Team—the U. S. Air Force.

No organization in the world gives young people a greater opportunity to do vital, responsible work.

For example, just a short while ago a 23-year-old Air Force lieutenant made a startling breakthrough in metallurgy. And a recent All-America tackle is doing advanced research in nuclear weapons.

If you have talent, you'll have a chance to show it in the Air Force. Your work can put you and your country ahead.

You can earn your commission at Air Force Officer Training School, a three-month course open to both men and women. To apply, you must be within 210 days of your degree.

For more information, contact the Professor of Air Science. If your campus has no AFROTC, see your Air Force recruiter.

U.S. Air Force

Ford Motor Company is:

challenge

Dale Anderson
B.A., Wittenberg University

At many companies the opportunity to work on challenging projects comes after many years of apprenticeship and a few grey hairs. Not so at Ford Motor Company where your twenties can be a stimulating period. There are opportunities to prove your worth early in your career. Dale Anderson's experience is a case in point.

After receiving his B.A. in Physics in June, 1962, Dale joined our College Graduate Program and was assigned to our Research Laboratories. Recently he was given the responsibility for correcting cab vibration occurring on a particular type of truck. His studies showed that tire eccentricity was the cause of the trouble. Since little change could be effected in tire compliance, his solution lay in redesigning the suspension system. Tests of this experimental system show the problem to be reduced to an insignificant level.

That's typical of the kind of meaningful assignments given to employes while still in the College Graduate Program—regardless of their career interest. No "make work" superficial jobs. And, besides offering the opportunity to work on important problems demanding fresh solutions, we offer good salaries, a highly professional atmosphere and the proximity to leading universities.

Discover the rewarding opportunity Ford Motor Company may have for you. How? Simply schedule an interview with our representative when he visits your campus. Let your twenties be a challenging and rewarding time.

THERE'S A FUTURE FOR YOU WITH... Ford MOTOR COMPANY

The American Road, Dearborn, Michigan

An equal opportunity employer

the Mecheleciv

VOLUME 23 MARCH - 1965 No. 4

page

ARTICLES

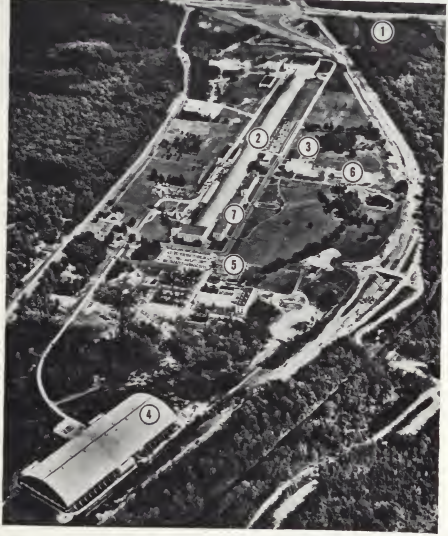
DEPARTMENTS

COVER

The cover this month was again done by Millard Carr, our Art and Layout man. See the editorial on page 7 for a complete description of the balanced life of the playboy engineer. (Surprise, there are no Indians this month.)

Published at the George Washington University by direction of the Engineers' Council. Published six times during the school year in October, November, December, March, April, and May. Second class postage paid at Washington, D. C. Address communications to Mecheleciv Magazine, Davis-Hodgkins House, George Washington University, Washington, D. C. 20006, or telephone 333-0173.

You are high over the Potomac River just 12 miles from the White House...and viewing 186 acres of extraordinary research activity



(1) The Washington Circumferential Highway allows speedy access to best suburban communities in the District of Columbia, Maryland, and Northern Virginia.

(2) HYDROMECHANICS LABORATORY facilities include this High-Speed Towing Basin almost 3/5 OF A MILE LONG, 50 feet wide, and 20 feet deep. This Laboratory is concerned with speed, stability, control and seakeeping qualities of floating or submerged naval designs, and with fundamental naval hydrodynamics.

(3) APPLIED MATHEMATICS LABORATORY—primary computing facility of BuShips—puts the latest computer systems to work on engineering computations, research logistics, numerical methods . . . and such special projects as mathematical simulation of the life cycle of nuclear reactors, automatic calculation of ship lines, etc.

(4) In this giant (5 acre) new Maneuvering and Seakeeping facility, both fixed and free-running models may be tested under any sea-state condition. You may also work with the High-Speed Phenomena Division at Langley Field, Virginia.

(5) AERODYNAMICS LABORATORY facilities include several wind tunnels—ranging from subsonic through hypersonic at Mach 10—which are used to determine and improve static stability, control and heat transfer characteristics of helicopters, VTOL's, supersonic aircraft, missiles, etc. Air flow studies also involve bomb design, bridge structures, aircraft turbulence when approaching carriers, and other government and private problems.

(6) Latest STRUCTURAL MECHANICS LABORATORY facilities are pressure tanks which permit the structural model study of hull structures for vessels to operate in the depths. There is also a tridimensional Static-Load Frame, a Pentagonal Test Pond, Explosion Pits, and a 600,000-pound Universal Testing Machine . . . everything required to help Navy scientists improve hull structures and resistance to attack.

(7) The ACOUSTICS AND VIBRATION LABORATORY was just established to intensify research and development of ships of improved detection capability, and reduced vibrations and underwater sound output. Fundamental and applied research in hydrodynamics, structural acoustics, mechanical vibrations, and signal processing are supplemented by conduct of acoustic and vibration trials, and development of acoustic and vibration instrumentation.

The OPERATIONS RESEARCH GROUP cannot be pinpointed as easily because it ranges over all the RDT&E activities at The Model Basin—hydromechanics, structural mechanics, aerodynamics and applied mathematics. Special applications today are in the fields of naval architecture, ship silencing, ship protection and weapons effects . . . setting realistic performance goals for ships and submarines in view of probable environmental factors . . . handling special externally-generated projects that tie in with DTMB capabilities . . . and making recommendations to the Technical Director as to improving research methods and orientation.

Of course, from this height you can't see much detail, and the chances are you can't guess what's going on. But on these 186 acres is a one-of-a-kind fundamental & applied research organization . . . a place you should seriously consider to begin your career in science or engineering. For, as the Navy's advanced activity for research into submarine, surface ship, aircraft, and missile design concepts, the David Taylor Model Basin can offer the recent graduate certain specific advantages hard to find anywhere else.

1. Work on research projects of unusual scope and recognized national importance.
2. Gain diversified RDT&E experience with the finest equipments and facilities of their kind.
3. Take graduate courses for advanced degree with Navy encouragement and financial help.
4. Reach the $10,000 to $12,000 level WITHIN 4 YEARS.
5. Attain recognized professional stature sooner, at which point a number of futures are available.

Whatever your technology—aerospace, electrical/electronics, mechanical, structures & materials—the Model Basin would like to talk things over. Contact Mr. S. Di Maria, Personnel Officer, directly for information, or check your Placement Office for on-campus interviews.

David Taylor Model Basin / U. S. Department of the Navy

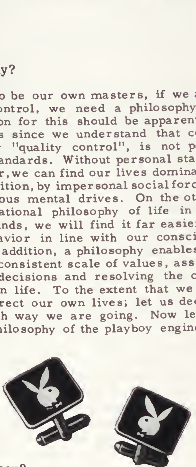
Washington, D.C. 20007
An Equal Opportunity Employer

In this editorial and the following, we wish to investigate a philosophy which we feel is being adopted by young, modern, professional engineers. We will call this "the playboy engineer's philosophy." The source of the phrase "playboy engineer" is a rather surprising definition of a playboy written by Hugh Hefner in his magazine of "entertainment for men." What we shall do here is combine the attitude of Hefner's playboy and the viewpoint of the truly professional engineer. This month we will simply concentrate on defining our playboy engineer. Next month we will examine the playboy engineer's morals: his ethics of work and play, his responsibility for the effects of engineering on society, and his attitude toward sex and birth control. But before we start, let us convince ourselves of the importance of a philosophy in general.

The PLAYBOY ENGINEER'S *Philosophy*

Why a philosophy?

If we are to be our own masters, if we are to have self-control, we need a philosophy of life. The reason for this should be apparent to us as engineers since we understand that control, especially "quality control", is not possible without standards. Without personal standards of behavior, we can find our lives dominated by obsolete tradition, by impersonal social forces, or by unconscious mental drives. On the other hand, with a rational philosophy of life in the back of our minds, we will find it far easier to bring our behavior in line with our conscious objectives. In addition, a philosophy enables us to establish a consistent scale of values, assists us in making decisions and resolving the conflicts implicit in life. To the extent that we are able, let us direct our own lives; let us decide ourselves which way we are going. Now let us consider the philosophy of the playboy engineer.



What is a playboy?

The playboy, as we mentioned before, was defined in a rather unexpected way in April, 1956, by Hugh Hefner when he said, "Is he simply a wastrel, a ne'er-do-well, a fashionable bum? Far from it: He can be a sharp-minded young business executive, a worker in the arts, a university professor, an architect or engineer. He can be many things, providing he possesses a certain point of view. He must see life not as a vale of tears, but as a happy time; he must take joy in his work, without regarding it as an end and all of living; he must be an alert man, an aware man, a man of taste, a man sensitive to pleasure, a man who -- without acquiring the stigma of the voluptuary or dilettante -- can live life to the hilt. This is the sort of man we mean when we use the word playboy." (This is not what most people mean when they use the word "playboy.")

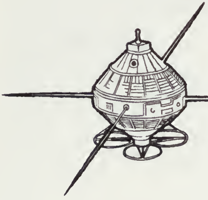
In principle, most of us find this idea of a playboy quite acceptable and even appealing. But to actually live the life of Hefner's playboy is to go against our entire Western heritage. We have been conditioned to accept hard work as a virtue, not for what it brings us, but just because it is work. We have been taught to hide our emotions, to refrain from "laughing out loud in public." These Puritanistic and Calvinistic attitudes are deeply rooted in our lives and the lives of our parents. These attitudes give us the feeling that man must be suppressed, restrained, and kept busy to prevent his animal-like nature from coming to the surface. Such attitudes and the feelings of guilt they produce must be re-evaluated before we can lead the life of a playboy engineer.

The playboy engineer's philosophy of life depends to a large extent on his self-concept. He views himself as a rational person with a free-will, a person responsible for his own actions. He feels that the object of a man's life should be happiness, not just today, but tomorrow too. So the playboy engineer has a well developed sense of responsibility. But he does not forget that along with responsibility goes the right to "life, liberty, and the pursuit of happiness."

—Continued on page 8

What is a professional engineer?

Before we can understand what it means to be a playboy engineer, we must recall what it means to be an engineer. The engineer has the task of taking the forces and materials of nature, studying them, and reshaping them to meet the needs of his fellow man. There are two important things to remember about the work of an engineer. One, he applies the knowledge gained by science. His job is not to find new knowledge, but to apply it. The engineer may sometimes get involved in basic research because the knowledge he needs does not exist, but when he does so, he is doing the work of a scientist, not an engineer. The second thing to remember is that the engineer's work is determined by the needs of man. These needs are usually material, but not always; he must very often consider the social, aesthetic, or even intellectual needs of man. The engineer's work in the space program, for example, is mainly directed toward the satisfaction of an intellectual need - man's curiosity about space.



Now the distinction between a professional engineer and an engineer is rather subtle. The difference lies in such words as excellence and significance. The professional engineer is actually interested in his work, not just the money it brings him; in fact, he is willing to do unrequired work to achieve excellence. He seeks to invest his work with wide and enduring significance; that is, he feels his work is important both to himself, his colleagues, and his fellow man.

The playboy engineer at work:

Now we are ready to combine the two attitudes -- that of the playboy and that of the professional engineer. We find it best to do this in two parts. We will describe the playboy engineer first at work and then at play. (In this respect, we are a little like the Playboy Clubs' "bunnies" who do not mix work and play either.) Going back to Hefner's original definition, we see that the playboy engineer "must take joy in his work, without regarding it as an end and all of living." We like to think that the playboy engineer will adopt the motto of Theta Tau, the professional

engineering fraternity: "Whatever thy hand findeth to do, do it with thy might." For then he will have the satisfaction that comes with doing a job well, and his work will be a source of real pleasure. But the playboy engineer is no grind; he never takes his "noble work" too seriously. He can laugh about it, and he knows that life can never be all work.

The playboy engineer at play:

The ever-increasing amount of leisure time in America is a result, if not the aim, of engineering effort: computers, automated plants, labor-saving equipment, and so on. Our playboy engineer feels that if he is responsible for creating all this leisure, then he ought to know how to use it best.

The first thing the playboy engineer thinks of when it comes to leisure is simply -- rest. He will go home, kick off his shoes, sit down in front of the fireplace, sip some of his favorite tension reliever, and just -- unwind. In this way he gives his mental batteries a chance to recharge. The playboy engineer views TV (rarely) as one form of entertainment, but by his nature he would rather be doing than viewing.

Physical exercise has an important place on the playboy engineer's list of leisure time activities. Since he knows how closely his mental output is tied to his physical reserves and since his chosen profession is one of mental activity, the playboy engineer is continually trying to improve his physical condition. He doesn't have to be told of the importance of good health if he is to "live life to the hilt." There is at least some form of good, tough physical activity in every day of the playboy engineer's life. He was doing daily exercises long before the President's Council on Physical Fitness even flexed a muscle.

Finally, we come to one of the most important uses of the playboy engineer's leisure time -- girls (or women, if he is lucky). Let us face "harsh" reality, the opposite sex is forever destined to be one of the greatest sources of natural pleasure in the life of the playboy engineer. So the realistic playboy engineer throws out all his senseless inhibitions, replaces them

with rational restraints, and thoroughly enjoys the other half of life. A word of warning is in order, for sex is also one of the most dangerous sources of pleasure. The playboy engineer knows well that sex must remain subjected to the power of reason, for nothing can dominate him faster, nothing can kill his chances for happiness easier than sex out of control. (We will discuss this subject further next month when we consider the playboy engineer's morals.)

Actually, there are other excellent ways for the playboy engineer to use his leisure. He has fencing, art, fishing, philosophical discussions, hi-fi, co-eds, travel, sailing, secretaries, books, nurses, — and more. If he is "an alert man, an aware man, a man of taste, a man sensitive to pleasure," the use of leisure time will be no problem, no matter how much of it he has.

—J.L.E.

We are interested in knowing, and publishing, your reaction to "The Playboy Engineer's Philosophy." Send all correspondence to: Editor, Mecheleciv Magazine, Davis-Hodgkins House, George Washington University, Washington, D. C. 20006.

JOB INTERVIEWS

Theta Tau

Professional Development Committee

When applying for a job, you certainly need to be neat in appearance and attitude, or the personnel man will reject you. But remember, the personnel man does NOT hire you; he sends you to an engineer who will decide whether or not you are the man for the job and if so, what your salary will be. It is also this same engineer who at the end of 6 months or so will pass judgement on your work and adjust your salary accordingly. Since all people he interviews are neat in appearance, and since by definition most people have average grades, what are the criteria these engineers use to determine whether or not you are the man for the job?

To be sure, very heavy emphasis is placed on speech courses, English courses, project labs & outside technical interests, and extra curricular activities. But why not ask the engineers themselves?

In a couple of weeks (Wednesday, March 31, 8:45 p.m.) three such engineers (one each EE, ME, and CE) will be here to explicitly state their individual criteria, and then answer any questions you may have. These three engineers are Mr. Ken Streeter, Mgr. of Technical Staff, Melpar Inc.; Mr. Dick Stevens, Project Mgr., American Machine and Foundry Co.; and Mr. W. E. Reynolds, Federal Commissioner of Public Buildings 1934-1954, presently consultant (structural) engineer. These gentlemen have hired hundreds of engineers; and there is not room to list them here, but they have a list of technical accomplishments that quite literally would make Mr. Einstein stand up and take notice.

LOWERCLASSMAN: Since heavy emphasis is placed on your choice of electives and use of time outside the classroom, this will be of great benefit to you in planning your schedule.

RESPONSIBILITIES IN LEARNING

by Kenneth Belford
Chairman of Press Relations Committee
Sigma Tau

A spirited, but adult, discussion of the relative responsibilities of the student and instructor in the process of learning began at 8:45 p.m., Thursday, February 25th in Tompkins Hall under the direction of Norm Seidle, President of XI Chapter of Sigma Tau. Panelists for this, the February edition of the Sigma Tau Open Forum, were Professors Hyman, Meltzer, and Graduate Student - Professor Bob Moore. In addition to the students and instructors gathered for the discussion, Dr. Mason, Dean of the School of Engineering and Applied Science, and Dr. Brown, Vice President, Dean of Faculties, G.W.U., were in attendance.

PANEL OPINIONS

The discussion period started with statements by the panelists revealing their views on the subject of learning responsibilities. Professor Hyman commented that when a student registers for a group of courses he commits himself to earnestly pursuing these courses to a successful conclusion. An instructor should determine the amount of work required for his course, and the student should be required to do this amount of work regardless of any extenuating personal circumstances (other than illness). Furthermore, probation should not be an excuse for raising a grade.

Professor Moore commented that the faculty member should prepare himself so as to emphasize the fundamentals. He should organize his lectures so as to cover a reasonable amount of material in the time allotted. The student, in turn, should keep up with the professor while in class, and have read the material to be covered before coming to class. If necessary, he should consult other texts to improve his understanding, and should do problems so he has an idea of what he really knows.

Professor Meltzer commented to the effect that you can lead a horse to water, but you cannot make him drink. The professor should be prepared, but it is the desire of the student to learn which will determine how much a person gets out of a course. The professor is there to present the material, but not to force the student to learn; this the instructor cannot do. Professor Meltzer further commented that the instructor can never be sure the material which is lucid to him is clear to the student. Therefore, dialogue in class is very important because it gives the professor an idea of how well he is presenting the material.

COURSE INTEREST

Following the formal statements by the panelists, Mr. Seidle threw the meeting open to discussion. The question was raised as to whether or not the professor should attempt to keep the course interesting. Professor Hyman commented that he felt courses should not be a bore. Professor Moore felt that the majority of the students are stimulated most by the anticipated use of a particular subject. Professor Hyman felt that this was a short sighted outlook. Students should not be interested because they feel a particular item will be useful after graduation, but, rather they should be concerned with acquiring a broadly based education. Some schools spend a disproportionate amount of time preparing a student to do a specific job, while at G.W.U. the emphasis is on a broad, general background. While in school a student should not be concerned with the salary he will earn after graduation. If he adequately prepares himself the salary will take care of itself. Courses providing preparation for a specific job will not provide an education adequate to cope with changes in the technology which may occur.

COURSE DUPLICATION

Chip Young, President of the Engineers' Council, asked if it were not the responsibility of the school administration and faculty to assure that there were not duplications in the courses given by different departments of the school. It was pointed out that some of the lower level engineering courses repeat subjects taught by the Physics or Mathematics departments. Professor Hyman commented that perhaps there was duplication and that this might be caused by lack of communication between departments; however, he disagreed that this duplication was undesirable. He felt the different outlook provided by taking the same material from different instructors was beneficial. Furthermore, he felt mathematics courses should be taught by mathematicians and physics courses should be taught by physicists, even if this did result in some duplication later by thorough engineering instructors. The best education can be provided by specialists. Professor Moore agreed with this philosophy and further commented that repetition was not a waste of time. Professor Meltzer felt it was a student responsibility to inform the instructor if they felt

they knew the material. In his teaching experience he had encountered few classes who had replied "yes" when asked if they had previously covered a particular point. Professor Muly commented that he felt repetition was the professional approach to teaching as opposed to trade school teaching methods where time is not available for re-covering ground previously covered.

Professor Hughes asked the panel if they felt it was the responsibility of the faculty to develop interest in a course. Professor Hyman answered that he did not feel it was a responsibility; however, he personally felt he was not doing a good job unless he did. In other words, while he did not feel generally that it was a faculty responsibility, he personally held himself responsible to maintain interest.

CURRICULUM PLANNING

The question was raised as to who should be responsible for determining whether or not a student has adequate preparation for undertaking a particular course. The question was brought up by a student who had transferred to G.W.U. On the basis of the catalog description of a course the student previously had, he was advised to take Ap. S. 59. However, after starting the course it became apparent the previous course had been inadequate. At this point the student was advised by the instructor to drop the course; however, having started, the student did not want to drop. Fortunately he passed the course. Doug MacDonald pointed out a similar case he was familiar with which did not end as happily. The panel was of the opinion that it was very difficult for the adviser to evaluate a course taught by a different school, and that the final decision and responsibility for choosing a course must rest with the student. It was pointed out that the student cannot properly evaluate a course from the brief description frequently given in the G.W. catalog. Professor Meltzer advised that any student in a questionable situation should talk to the instructor who will teach the course. With a few questions he can quickly evaluate the background of the student. Furthermore, if a student finds himself in a course beyond his depth, he should have the courage to drop.

Bill Kolb queried the panel for their opinion as to whether or not an instructor should set himself up as the guardian of the particular profession he is teaching. He cited the example of a professor, no longer with the university, who graded majors in his particular discipline more harshly than students in other categories. It was agreed that this was not a good practice; however, the instructor named was praised for his teaching ability.

OTHER STUDENT'S COMMENTS

Jerry Edwards questioned whether a student had the right to complain to higher authority if he was dissatisfied with a particular instructor. Professor Meltzer observed that a student had the right, but that he should discuss the problem with the instructor before going to higher authority. If the teacher is really poor, it is the duty of the students to complain. Doug MacDonald pointed out that in one course he had taken, the instructor had had so many complaints about the material being covered that he had changed the course to agree with the wishes of the students. Professor Hyman commented that he felt this was a very dangerous practice.

On the problem of getting students to ask questions, a student offered the thought that many students are afraid of revealing their ignorance. Professor Hyman commented that the very act of signing up for a course was an admission that the student was ignorant of the subject matter. Professor Meltzer commented that all instructors have been students in the past and many still are; therefore, they appreciate the problems of the student. Joe Martino, sitting in the hallway, agreed that students are afraid of revealing their ignorance. He felt the problem was particularly bad in courses he has taken with graduate students. They seemed particularly afraid to admit they did not understand. Professor Hyman observed that silence does not always indicate understanding. Tom Dillon asked if the panel felt professors should ask questions if the students do not. Professor Meltzer felt a professor should frequently ask if there are any questions. If this does not draw out questions, then the instructor should begin asking questions. Vice President Brown told of a law professor he knew who simply walked out if the class failed to discuss the subject under consideration. Students found they had to be properly prepared just to keep the professor in the room. Professor Meltzer told of one of his professors who asked a question and, when no one could answer, walked out with the comment that he would not be back to teach the course until someone came to his office with the answer.

A student commented that he felt professors should give the class some indication of the objective of a course. Frequently the student does not know why he is studying a particular type of problem. The student felt this was particularly true in mathematics courses. Professor Hyman commented that frequently it is difficult to define the objective of a course. In a university the main objective may be to develop a way of thinking, and the particular problems are just ways of achieving this. All an instructor can do is outline the specific material to be covered. Professor Moore commented that usually the students do not understand a subject well enough in the beginning to grasp the objective if the professor did attempt to define it.

Doug MacDonald offered the comment that he felt it was a student responsibility not to adversely comment on courses or instructors. Frequently the wrong impression is given, causing other students to enter a course with unjustified apprehension. Very often more is learned from instructors with "task master" reputations than from those who are more easy going.

At this point, although more hands were up, Mr. Seidle terminated the discussion because the Forum had already gone five minutes overtime. Dean Mason and Vice President Brown were then formally introduced to the gathering by Mr. Seidle.

THE ENGINEER'S ROLE IN GOVERNMENT

by Douglas MacDonald

Governmental policies designed to deal with the problems created by advances in technology are being made by those persons responsible for the advances. Technological progress results from the contributions of several academic fields such as science, engineering, applied mathematics and others. Although the primary objective of this essay is to provoke thought and discussion among engineers as to their role in the governing of this nation, the arguments presented are based on ideas present in the scientific community as a whole. This includes scientists, applied and pure mathematicians, etc., as well as engineers. Just as the ideas which form the basis of this essay came from the scientific community as a whole, the observations and conclusions drawn apply equally well to the whole scientific community.

SCIENCE POLICY MAKING

Involvement of the scientific community in the affairs of government is a relatively recent development. The emergence of the atomic bomb thrust upon its creators the responsibility of governmental policy decisions to cope with this tremendously powerful device. Ever since then an ever increasing number of questions are being asked of the scientific community by the government. The government wants to be informed on radiation control, automation, missiles, pesticides, transportation and many more.

Lack of understanding on the part of government policy makers of the highly technical information supplied to them has resulted in the transference of the policy making. The scientists, engineers or mathematicians who in the first instance were called upon to give advice, now are asked to make the decisions.[1] Today there exists a group of eminent scientists and engineers whose job it is to create a science policy for the United States. There is some discussion as to whether the scientific community should have a monopoly on making science policy, but it is true that once a certain policy or plan has been formulated it is the responsibility of professional scientists and engineers to implement it.[2]

ACTIVITY IN POLITICAL AFFAIRS

Advising for, creating, and implementing scientific policy have until the past few months been the only role the scientific community played in the governing of this nation. The presidential election witnessed the emergence of such groups as Scientists and Engineers for Johnson and Scientists and Engineers for Goldwater. These groups demonstrate an ever increasing role the scientific community can play in our government. The scientific community can be an effective political force working to elect those individuals they feel best represent the interests of science. The fact that many eminent scientists and engineers felt compelled to join one citizen group or another does not mean that the whole scientific community is prepared to leap into the political arena and take up sides. Witness the formation of a "non-partisan" 1964 Scientists Committee for Information dedicated to "'impartial and accurate information' on scientific issues that may arise in the campaign."[3] In any case it is the prediction of some, like Rodney W. Nichols head of a systems analysis research group at Melpar, Inc., Falls Church, Va., that "scientists, engineers, doctors and other professionals will participate more fully in future political campaigns, both national and state."[4] What effect this increased activity in political affairs by scientists and engineers will have on the scientific community is hard to say. It definitely is a "significant development in the life of the scientific community."[5]

The recent rise of scientists and engineers as a political force in this country has been paralleled by a somewhat similar situation in Britain. There the role of science in government had become an issue in their elections. Before the British election the magazine International Science and Technology carried an interview "A Science-Based Government." The interview featured Quintin Hogg, Britain's minister of science, and R.H.S. Crossman, the Labour party's spokesman on science.

Our good friends the British are just beginning to admit that the technical expert should make the scientific decisions.[6] The universal nature of the problem of the role of science and technology in government attests to its importance both for now and in the future.

1. Emmanuel G. Mesthene, "Can Only Scientists Make Government Science Policy?," Science, 145, (July, 1964), 237.40.
2. Ibid.
3. D.S. Greenberg, "The Election: Partisan Activity of Scientists Unlikely to Sow Discord in Scientific Community," Science, 146, (October, 1964), 232.4.
4. "Professionals Emerge as Political Force", Aviation Week, 81, (October 1964), 26.
5. Greenberg, op. cit.
6. "A Science-Based Government", International Science and Technology, 33, (September, 1964), 33.40.

Douglas MacDonald is a full-time E.E. student who expects to graduate in June, 1965. This D.C. resident then hopes to go on to graduate work. Doug is a member of Tau Beta Pi, the national engineering honorary fraternity. This paper is the winning essay of his pledge class.

RESONANCE IN YIG CRYSTALS

by Scott LeBeau

It is well known, that if, a piezoelectric crystal is placed between two plates and an alternating voltage, of the proper frequency, is applied to the plates, then the crystal will resonate in a longitudinal mode (see figure 1). When this circuit is

FIG. 1—(a) Piezoelectric Crystal between two Plates (Edge View). (b) Equivalent Electrical Circuit.

employed, it turns out (by applying the classical electro-mechanical analogy) that the crystal plate combination can be represented by its electrical analogy shown in figure 1(a). The capacitor, C, represents the compliance of the crystal, the inductor, L, the mass, and the Resistor R the viscous damping factor inherent in the solid. The other capacitor, C', represents the capacitance due to the plates. The interesting result which can be observed from this arrangement is that, for some crystals and crystal cuts, the crystal can be made to resonate with a very low energy loss per cycle i.e., with a very large quality factor, Q (Q is defined as 2π times the energy stored in the crystal per cycle divided by the energy dissipated in the crystal per cycle). This fact, along with the crystal's high resonant frequency stability with respect to changes in time and temperature, makes the crystal very useful for application to precise frequency crystal oscillators.

HIGHER ENERGY GAINS

More recently, it was discovered that certain Ferrite crystals, notably Yttrium Iron Garnet(YIG) can be made to resonate in a shear mode, with very high Q, if the crystal is placed in a D.C. magnetic field and driven with an r.f. magnetic field perpendicular to the D.C. field (see figure 2). The r.f. field is produced by a current which flows through a coil which is wound around the crystal. It is hoped that values of Q of the order of 10^7 can be obtained in this manner as compared with the maximum of about 5×10^5

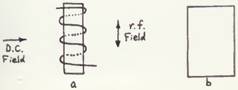


FIG. 2—(a) Edge View of YIG Crystal in Coil. (b) Front View.

obtained with the proper cut of a quartz crystal (piezoelectric crystal). The practical value of this device would be the same as that of the piezoelectric crystal, only it would be more efficient.

HOW IT WORKS

A possible theory which will serve to explain the reason that the crystal moves at all under the influence of the magnetic fields will now be given; the simplified case of the YIG plate will be discussed here.

The D.C. field is oriented in such a direction as to be perpendicular to the plane of the plate, while the r.f. field is oriented so as to alternate in a direction normal to the D.C. field, in the direction of the longer dimension of the plate (see figure 2(a)). The D.C. field serves to line up the magnetic dipole domains (YIG is a ferrimagnetic substance) and then when the r.f. field is introduced normal to this one, it tends to line up the dipoles in this new direction (normal to the direction in which they want to be--see figure 4). The result is a twisting effect which is produced by the shear forces induced by the r.f. field, and the crystal deforms in the manner illustrated in figure 4(b). This deformation process is repeated first in one direction, then in the other, for every cycle of the current flowing through the coil, which encircles the crystal. If the r.f. field is made to alternate at the natural frequency of the crystal, then the crystal will resonate at this frequency with a very high Q.

ANALYSIS OF THE CRYSTAL-COIL COMBINATION

As in the case of the piezoelectric crystal, it is also possible in the case of the YIG-coil arrangement to write down the electrical analogy (see figure 3). The analysis of this circuit, i.e. the analysis of the crystal-coil combination

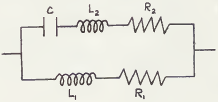


FIG. 3—Equivalent Electrical Circuit of YIG-Coil Combination.

--Continued on page 14

Scott LeBeau is a full-time E.E. student who expects to graduate in June, 1966. In his first year at G.W., Scott was the winner of Sigma Tau's Outstanding Freshman Award. In another acknowledgement of his academic prowess, the following year Tau Beta Pi awarded him their Outstanding Sophomore Award.

THE NEW CURRICULUM

Keep It or Abolish It?

by Norman Seidle

Speaking at the September Open Forum, Dean Mason said that this new curriculum is an experiment, and it is not known what will be the outcome of this experiment. That is to say, fellow students, we are guinea pigs! It is very true indeed that those who did not switch in the new curriculum were left up a creek. But after filtering out this legitimate beef, what is the reaction to the new curriculum? What is your reaction?

Al Fratantuono says he sure is glad he is under the old curriculum. Many people are scared stiff of the comprehensive exams. Others, such as the author, have nothing but praise (along with a few suggestions for improvement) for the new curriculum. But unfortunately most of us do not know what we are talking about when we criticize the curriculum.

That is to say, I want the curriculum which will best prepare me for being a good citizen, engineer, and leader; but I don't really know what constitutes any of these — especially the engineering part. Dean Grisamore has won widespread acclaim for his "Lectures in Miniature" (WMAL radio) in which he explained the future of engineering as a profession, what engineering should be as a profession, and how to prepare to enter engineering. The curriculum here at G.W. can not help but reflect Dean Grisamore's views toward how to best prepare me for being a good citizen, engineer, and leader. If Dean Grisamore, along with other faculty members, is correct, I'll be sitting on top of the world; but if he is wrong, I've been had. If he is someplace inbetween, I'll probably end up someplace inbetween with a lot of room for my personality to push me one way or another. In other words, I like this new curriculum, and I have some suggestions for improving it; but I am still too young and too inexperienced to know for sure if what I now believe is best for me really is what is best for me.

However, this does not mean I cannot intelligently discuss and criticize the curriculum. On the contrary, I intend to do just that in a few days at the Open Forum when we openly discuss the new curriculum -- its purpose, its advantages, its shortcomings, whether or not to abolish it, and so on. Al Fratantuono will be on the panel, and he will tell why he does not like the new curriculum and why it should be abolished. Dean Grisamore, who is intently interested in this subject, will be on the panel to discuss all aspects of this curriculum. Along with Al and Dean Grisamore, Prof. Ojalvo, who is becoming well known as a good teacher, advisor, and friend, will tell just exactly what he thinks of the new curriculum. Following this brief panel presentation and discussion, the floor will be open for active participation by all who wish to discuss the matter.

Date: This coming Wednesday, March 17.

Time: 8:45—10:00 p.m. (after your 6:10—8:40 marathon class)

Place: TH 207

ENTER or EXIT AT ANY TIME!

RESONANCE IN YIG CRYSTALS—from page 13

(analysis of the classical electric analogy is equivalent to the analysis of the mechanical system) is what is of interest here. The impedance of this circuit can be calculated and it turns out to be $\frac{(1-L_2C\omega^2+J\omega CR_2)\ (Cj\omega L_1+R_2)}{j\omega C(j\omega L_1+R_1 1+C1-L_2C\omega_2+j\omega CR_2}$

This expression reduces to $\frac{A_2(j\omega L_1+R_1)}{j\omega L_1+R_1+R_2}$ when $\omega = \frac{1}{\sqrt{LC}}$, the resonant frequency of the simple LC oscillator. Also it can be seen, since the impedance is less at resonance, that more current will flow through the circuit for a given applied voltage, if the applied voltage is at the resonant frequency of the LC oscillator. In the actual performance of the experiment, it is found that 1) the crystal does have a resonant frequency, and 2) that when a voltage (force) is applied to it at this frequency it resonates (performs a periodic mechanical motion at a high velocity). So the motion is completely described by the electrical system if it is noted that voltage is analogous to force and motion (velocity) is analogous to current.

FIG. 4—(a) Edge View (Highly out of proportion — the thickness is actually much less than the length) when no r.f. magnetic field is applied.
(b) Edge View (Highly exaggerated proportions and deformation) when D.C. bias field and r.f. field are applied.

STILL WORK TO BE DONE

At least in theory, therefore, it is possible to use a YIG crystal as a source for a very stable frequency source. In practice however, there are still problems to solve. For example, the required D.C. magnetic field to produce saturation (the highest values of Q occur above saturation) is of the order of 2 to 3 kilogauss. This is a very large magnetic field which required a large magnet to produce.

MECH MISS . . .

Our pretty Mech Miss this month is Pam Jean Gay. Miss Gay transferred to George Washington from The University of Maine where she was a member of Chi Omega Sorority. Pam is a junior majoring in Physical Education. She spent last summer studying Art in Europe. Her hobbies include water and snow skiing, horse-back riding and horse training.

If you have time and interest, you may find some interesting facts about Pam if you solve the following third order equation:

$$X^3 - 96X^2 + 3024X - 31104 = 0$$

The Mecheleciv staff would like to thank Eastern Air Lines, Inc. at National Airport for the use of one of their Super Electra Airplanes as background for the Mech Miss pictures.

OPERATIONS RESEARCH
as a Career

by Dr. Frank E. Bothwell

On a warship somewhere in the Pacific, a civilian mathematician discusses plans for a major exercise with a Navy fleet commander;

In an office near Washington, D. C., a physicist, an economist, a chemical engineer, and a naval architect analyze the probable effect of a new ship propulsion system on the Navy of the '70s;

In the Pentagon, a group of scientists, Naval officers, and Defense officials study an array of equations which represent the mathematical model of a proposed missile system.

These pursuits are all examples of the work of scientists engaged in Operations Research. They also represent some of the activities of CNA - the Center for Naval Analyses of The Franklin Institute - a non-profit scientific organization which conducts operations research for the U. S. Navy.

Operations Research (OR for short) is a rewarding and challenging profession. It demands a rare combination of analytical ability and creative imagination in addition to advanced mathematical and technical knowledge. For young people capable of meeting its requirements, it is worth serious consideration as a career.

NEW PROFESSION

Twenty years ago, the words "operations research" had meaning to only a few hundred scientists, military officers, and government officials engaged in classified defense activities. Among this group were members of the forerunner of the Operations Evaluation Group (OEG), the nation's first military OR organization. OEG is now one of the components of the Center for Naval Analyses.

Today, Operations Research is an established profession. In 1963, according to the Operations Research Society of America, about 6800 scientists worked at it full-time, on a wide variety of civilian and military problems.

Despite the present importance and expected future growth of OR, few career guides mention it as a separate profession. Many colleges and universities offer OR courses in their undergraduate and graduate curricula. But these are generally incorporated in programs for such traditional disciplines as Engineering and Business Administration. Relatively few schools grant degrees in Operations Research itself.

THE NATURE OF OR

Although there is no simple definition of operations research, it has been described briefly as:

The use of scientific method to study operations to give executives an analytical basis for decisions that will increase the effectiveness of their organization in carrying out its basic purpose.

Operations research seeks answers to practical problems of improving the performance of combinations of men and machines engaged in purposeful activities. It is concerned largely with "real world" activities, as opposed to the "ideal world" of many theoretical studies. Unlike much of physical science, it is also a research field in which results may be obtained within a relatively short time.

Although there are many kinds of objectives, organizations, operations, alternatives, and measures of effectiveness, OR has shown that many apparently different executive problems actually have many similarities, and that certain generalized methods can be used to solve them.

DEFINING PROBLEMS

One class of OR problems is concerned with determining the best way to distribute limited resources (men, money, equipment) among parts of an operation to obtain maximum effectiveness for the whole organization.

At the Center for Naval Analyses, for example, OR techniques are used to help the Navy maintain a balanced procurement program by determining the relative needs for submarines, surface ships, aircraft, missiles, and equipment.

While studying an operation, the OR analyst seeks answers to many questions:

What are the objectives?

How can the effectiveness be measured?

What major factors influence the results of the operation and how are they related to each other?

What changes can be made in the operation now or in the future?

How will they affect the results? What will they cost?

From among the alternatives, which one offers the greatest improvements in effectiveness for the whole operation?

Finding answers to such questions often requires a team, since one man may not have the necessary depth and variety of knowledge. A major research project for CNA, for example, may require the coordinated talents of mathematicians, physicists, engineering specialists, and economists.

Many of these questions, especially those related to the future, cannot be answered with certainty. In handling these, the OR analyst may draw heavily from theories of probability, indicating the degree of uncertainty in the results of his study.

Dr. Frank E. Bothwell, Chief Scientist of the Center for Naval Analyses of The Franklin Institute, is a graduate of Massachusetts Institute of Technology, where he received both his B.S. and Ph.D. in Mathematics.

THE TOOLS OF OR

Many articles about computers and new management methods have described OR methods without necessarily mentioning OR itself. Such terms as simulation, dynamic programming, linear programming, game theory, and probability theory identify a few of the tools of the OR analyst. In broadest terms, OR uses the analytical methods of mathematics and logic, the principles of science, and whatever other knowledge may be pertinent to define and solve problems. If it helps to solve an OR problem, it's an OR tool.

Many man-machine operations can be described in terms of a mathematical "model"; that is, a mathematical expression which describes the operation. This model is analogous to the physical scientist's hypothesis, and like his, must be tested to determine whether it does coincide with observed phenomena. If it does prove to be a reasonably accurate representation of actual operations, factors in it can then be varied at will to determine the effect of making changes in the actual operation. For instance, those factors in a model of an air defense operation which represent the speed of the attacker can be varied to see what effect improved enemy performance would have on defenses. Similarly, the factors representing our defensive sensors and weapons can be varied to see how they improve our abilities.

Thus, a reasonably good model permits an analyst to vary the capabilities of opposing forces in any logical dimension, and to predict the probable, or expected outcome of future encounters. However, his predictions will be no better than his model and will not be applicable to any one encounter, but to the average of many encounters.

If several alternative factors, representing potentially competitive new systems, can be successively entered in the model, and if their costs can be predicted with at least some relative accuracy, their cost effectiveness can be approximated. That is, the model can indicate the relative effectiveness of each alternative system, and the ratio between effectiveness and cost thus derived. Such reiterative computations for alternative systems under varying operational conditions can easily become so arithmetically ponderous that their solution is only practical on a high speed computer.

If an analyst is to erect a useful model, he must be on something like intimate terms with the operation. He must be not only mathematically competent, but must also be an excellent observer and data evaluator.

UNUSUAL VARIETY

At CNA operations analysts work on problems of undersea, air, surface, amphibious, and electronic warfare and defense. They also use OR techniques in questions of logistics strategy, and the application of new technology to naval operations of the present and future.

OR groups also work on a variety of problems for the other military services and for the Department of Defense. Other OR groups are concerned with such matters as production scheduling, inventory control, marketing, determining the best location for a new plant, and reducing traffic congestion on the highways and in the air.

OR AND THE EXECUTIVE

Operations research exists to help the executive, not to replace him. Although the analyst may offer recommendations for action, he does not make the final decision.

An OR analyst provides research and advisory service, concentrating on those aspects of an operation which can be treated logically and quantitatively.

--Continued on page 28

FACULTY SPOTLIGHT

ASSISTANT DEAN NELSON T. GRISAMORE

In October 1950, Nelson Grisamore joined the George Washington University as a Research Associate on the staff of Electronics Research Laboratory. He was later appointed Director of Electronics Research Project and Computer Research Project. He was appointed in September 1956 to be Assistant Professor of Electrical Engineering and by September 1960 had earned the status of Professor and Executive Officer of the Electrical Engineering Department. Dean Grisamore achieved his present title, Assistant Dean (Research) and Director, Center for Measurement Science in the School of Engineering and Applied Science in September 1962.

Prior to joining the George Washington University staff, Dean Grisamore held a position as a physicist in the Applied Physics Laboratory at the Johns Hopkins University and a Project Engineer on the NDRC Contract at George Washington University.

His formal education includes a bachelor's degree in Physics with a Chemistry minor and a master's in Physics with a Math and Astronomy minor, both received from the University of Illinois. He received his Ph.D. in Physics from The George Washington University.

Even with such an impressive background and many years of association with The George Washington University, few people are familiar with his present activities as Assistant Dean and faculty member of the School of Engineering and Applied Science.

His main duty is that of locating sponsors for research projects. This very often necessitates a great deal of time away from the campus. The purpose of his travels is to familiarize others with the facilities and talents available at the School of Engineering and Applied Science.

Many of us might be wondering how this research benefits the School. Dean Grisamore feels that "the purposes of research are:

(1) to provide for professors the time and wherewithal to keep up in their field,

(2) to provide jobs for student employment, and

(3) to obtain equipment for the School."

He also mentioned that as an additional advantage it helps to establish the School's name outside the local area.

Listed among his many professional and honorary society memberships are Tau Beta Pi and the IEEE.

Dean Grisamore is also very active outside the University. His publications on subjects related to his field are numerous. He recently was the curriculum advisor and an instructor in a special Metrology training course at the Sheffield Corporation. Presently he is a consultant to several research corporations.

Any person with the qualifications and experience that Dean Grisamore has would be a valuable asset to any university -- but fortunately for us, he is a member of our staff.

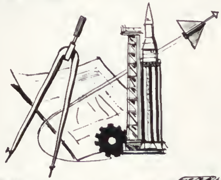
CONSTRUCTION

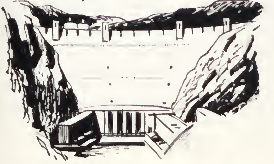
THE ARMY CORPS OF ENGINEERS

offers you a challenging civilian career with:

■ The world's foremost and largest engineering organization in the construction field, pioneering new and advanced engineering practices and concepts.

■ An organization whose work embraces virtually the entire range of modern engineering in the construction field. Projects include research into basic science, engineering investigations and regional planning; design, construction, operations, maintenance, and management of hydro-electric power dams, flood control facilities, harbors and navigable streams; design, construction and maintenance of family housing, runways, hangars, roadways, hospitals, and nuclear power installations; and construction of intercontinental ballistic missile and space launching sites. In addition are the allied fields of cartography, geodesy, mathematics, and engineer intelligence.





■ An organization that recognizes each engineer as an individual, providing well-rounded career development programs with on-the-job training; courses at government expense in colleges, universities, and seminars as necessary to assure steady progression to top professional and managerial levels; encouragement and assistance in attaining professional registration and recognition; and an opportunity to win national and international awards.

■ An organization with offices and projects in nearly every one of the 50 States and in many foreign countries that encourages employees to further their development by accepting new and challenging assignments.

■ An organization which provides excellent rates of pay with liberal fringe benefits, including generous retirement annuity, complete health and life insurance coverage, paid vacation leave, military training leave with pay, generous sick leave; and special pay awards for outstanding performance and suggestions that improve operating efficiency.

If you're thinking this is all too good to be true, you're wrong! All of the above is available to you in a civilian engineer career with the U. S. Army Corps of Engineers. If you are interested, you can get further information from the Chief of Engineers, Department of the Army, Washington, D.C. 20315.

AN EQUAL OPPORTUNITY EMPLOYER

WRITE FOR AN ILLUSTRATED BROCHURE "YOUR CAREER."

CAMPUS NEWS

STUDENT GOVERNMENT

by Bob Mullen
Engineering School Representative

This is the first in a series of reports dealing with my interpretation of Student Council and Engineer's Council proceedings and their effect on the engineering student and what you can do to strengthen Student Government

The Student Council under the leadership of President Skip Gnehm has met twice since the indoctrination of the new members. There is a feeling of optimism that perhaps this Council can achieve more than just the organization of "Joe College activities." While activity is the single most important area of Student Council jurisdiction, such projects as student-faculty relations, the orientation and registration proceedings, and a new constitution are high on the docket for consideration and revision. Hopes are high that the new constitution will be ready for student referendum by May 1.

Project #1: Take the time to study carefully each section of the new constitution. If passed, it will affect the remainder of your college life at George Washington University.

We can only hope that the enthusiasm shown so far by the new Student Council will not be quenched by final exams and summer vacation.

The Engineer's Council has announced that elections will be held on March 10 and 11.

Project #2: Vote on one of these days for your representatives on the Council (Introductory, Intermediate or Advanced). 148 engineers voted in the Student Council Election. For the Engineer's Council election there will be booths in Tompkins Hall rather than two blocks away so we see no reason why we can't double the Student Council vote total.

I would welcome your comments on Student Government. Written remarks will be considered for publications in future magazines.

SIGMA TAU

On Wednesday evening, March 17, Sigma Tau will sponsor an Open Forum during which everyone will have an opportunity to express their feelings toward the new curriculum.

Prior to the Open Forum, elections for next year's officers will be held at the regular business meeting.

In recognition of their superior professional attainment, the following gentlemen were elected to honorary (alumni) membership in Sigma Tau:

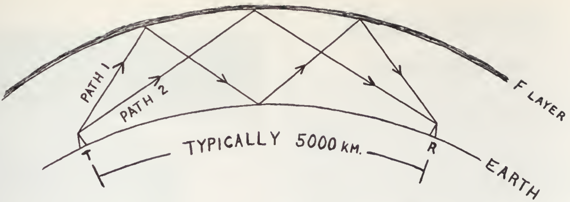
Dr. L. dePian
Dr. R. Heller
Mr. D. Anand
Mr. F. Lebib

If anyone has any ideas of topics of general interest which they would like to see aired at an Open Forum, please contact any Sigma Tau member or write a letter to Sigma Tau explaining the topic you would like to have discussed.

THETA TAU

Basketball is drawing to a close with the "good guys" maintaining an even record (5-5). Leading scorers are Stacy Deming and Orv Standifer. Other consistent performers (they show up for most of the games) are Chip Young and John Jenkins. Low scorer thus far is playcoach Bob Mullen. Hopes are high for the bowling and volleyball teams as many lettermen are returning.

Plans are underway for a guest speaker in our Professional Development Series (see article on page 9). An exchange, our annual picnic, and perhaps some additional outings are planned for this spring. The banquet and ball will be held in conjunction with the Washington Alumni Association and will commemorate the 30th Anniversary of Gamma Beta Chapter.



APPLICATION OF VOCODERS TO COMMUNICATIONS SYSTEMS

by Kenneth R. Belford

A vocoder is a device used for converting an analog voice signal to a binary digital data stream. The conversion is accomplished by a process of analyzing the voice frequency spectrum as opposed to sampling techniques which produce a signal requiring a wider bandwidth than the original analog signal. The binary output of the vocoder is a data stream with a bit rate corresponding to a frequency considerably lower than the highest frequency present in the voice frequency spectrum. Voice frequency communications channels usually employ a spectrum of approximately 300 to 3400 cycles per second. Vocoder bit rates of 2400 baud (bits/second) are typical, although units working at 1200 baud are available. A transmission rate of 2400 bits/second corresponds to a frequency of 1200 c.p.s. If this data stream is used to modulate a radio frequency carrier, a direct economy of more than 2.5 to 1 in bandwidth can be obtained, assuming proper modulator and receiver design. In addition, the vocoder is quite tolerant of errors in the received bit stream and thus tends to "clean up" a noisy voice circuit. A major advantage for military users is the fact that a vocoder bit stream can be encrypted by conventional data encryption devices.

MULTIPATH PROPAGATION

Vocoders have been successfully employed on high frequency (3-30 mc/s) radio communications circuits. A problem inherent in the use of high speed data streams on h.f. radio is that of multipath propagation. The F layer of the ionosphere, via which h.f. radio energy normally propagates, is relatively efficient and will return h.f. radio waves even though their angle of incidence is relatively low. Thus it is possible for the transmitted energy to arrive at the receiver via two, or even more, paths as shown in Fig. 1. Electromagnetic energy is frequently thought of as traveling from place to place almost instantaneously; however, in free space, EM energy actually requires approximately 3.33 microseconds to travel one kilometer.

$$\frac{300 \times 10^6 \text{ meters /second}}{1 \times 10^6 \text{ usecond/second}} = 300 \text{ meters/usecond}$$

$$\frac{1}{300 \text{ m/usec}} = 3.33 \times 10^{-3} \text{ usec/m.} = 3.33 \text{usec/km.}$$

At a transmission rate of 2400 bits/second each bit is approximately 417 microseconds in length. Therefore, if path 1 differs in length from path 2 by $\frac{417 \text{ usec}}{3.33 \text{ usec/km}} = 125$ km a given information bit will arrive at the receiver twice; the second arrival displaced a full bit length from the first arrival. This, of course, can cause errors in the received data. Even greater delays are commonplace in h.f. radio propagation, and, in practice, a strong echo displaced a half bit length will produce an error. To overcome this problem, equipment has been designed to convert a 2400 baud serial bit stream to a group of 32 parallel 75 baud streams. These lower speed bit streams can be used to modulate keying equipment normally used to transmit teletype signals. A standard method of transmitting teletype information is to frequency division multiplex sixteen 100 w.p.m. (75 baud) channels into one 300 to 3400 cycles/second voice channel, and transmit this signal over a single-sideband radio circuit. Thus a 2400 baud vocoder signal can be FD multiplexed on two voice channels. This, of course, is wasteful of bandwidth; however, the improvement in audio signal to noise ratio provided by the vocoder over a conventional s.s.b. h.f. radio voice channel is considered worth the sacrifice.

The vocoder will provide good intelligibility with an error rate of one error per hundred transmitted bits. This is an order of magnitude greater than can be tolerated for satisfactory teletype transmission and two to three orders of magnitude greater than can be tolerated on data channels which do not employ some type of error correction.

OTHER APPLICATIONS

In addition to h.f. radio systems, vocoders have been successfully tested on ionospheric scatter communications systems. Ionoscatter systems operate at frequencies near 50 mc/s and employ high transmitter power, high antenna

—Continued on page 30

Kenneth Belford, B.S. (Electrical Engineering) is employed by Page Communication Engineers, Inc., where he is working with communication systems. This paper was written as a Sigma Tau pledge requirement.

SOLVING SYSTEMS THE EASY WAY

by George W. Saxton

> George Saxton is a full-time E.E. student. He expects to graduate in June, 1965. At the present time George is busy working on the Navy Logistics Reseroch Project. He is a member of Sigma Tau for which this paper was written as a pledge project.

Quite often in engineering problems and applications, there arises a need to solve complex systems of linear equations. When the number of unknowns in such a system exceeds three or four, their solution by standard methods (e.g. Cramer's Rule) usually involves a great deal of arithmetic calculations—often more work than seems worthwhile.

Presented below is a method for solving systems of linear equations, devised by PRESCOTT D. CROUT of the Massachusetts Institute of Technology, which involves only about half as much work as a matrix multiplication--considerably less than in the example cited above.

As presented here, the method is applicable to a system of n equations in n unknowns. There are three major steps in finding the solution by this method: first, the setting down of an original n x n+1 matrix; second, the determination of an "auxiliary" matrix; and finally, the calculation of the solution matrix.

Given a set of equations of the following form,

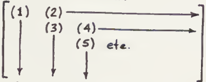
$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \cdots + a_{1n}x_n &= c_1 \\ a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \cdots + a_{2n}x_n &= c_2 \\ a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + \cdots + a_{3n}x_n &= c_3 \quad (1) \\ \cdot \quad \cdot \quad \cdot \quad \cdots \quad \cdot \quad &\cdot \\ a_{n1}x_1 + a_{n2}x_2 + a_{n3}x_3 + \cdots + a_{nn}x_n &= c_n \end{aligned}$$

the original matrix is made up of the coefficients a_{ij} and the terms c_i; thus:

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdot & \cdot & \cdot & a_{1n} & c_1 \\ a_{21} & a_{22} & a_{23} & \cdot & \cdot & \cdot & a_{2n} & c_2 \\ a_{31} & a_{32} & a_{33} & & & & a_{3n} & c_3 \\ \cdot & \cdot & \cdot & & & & & \\ a_{n1} & a_{n2} & a_{n3} & & & & a_{nn} & c_n \end{bmatrix} \quad (2)$$

THE AUXILIARY MATRIX

The auxiliary matrix is obtained by first determining the first column, then the first row except the first term, then the second column except the first term, then the second row, except the first two terms, etc. In other words, progress through the matrix is in the order 1, 2, 3, 4, etc. as shown below:



The rules for determining the elements, b_{ij}, of the auxiliary matrix are as follows:

(a) The first column of the auxiliary matrix is identical to the first column of the original matrix; i.e.,

$$b_{i1} = a_{i1}, \qquad i=1,2,3,\ldots,n \qquad (3)$$

(b) The elements of the first row of the auxiliary matrix are equal to the corresponding elements of the original matrix divided by the diagonal element; i.e.,

$$b_{1j} = a_{1j}/b_{11}, \quad j=2,3,\ldots,n+1 \qquad (4)$$

(c) Define an index parameter l; let l=2. This parameter is used to control progress through the matrix in the following steps.

(d) The next column is given by

$$b_{il} = a_{il} - \sum_{k=1}^{l-1}(b_{ik}b_{kl}), \quad i=l,l+1,\ldots,n \quad (5)$$

(e) The next row is given by

$$b_{lj} = a_{lj} - \sum_{k=1}^{l-1}(b_{lk}b_{kj}) \ /b_{ll}, \quad j=l+1,l+2,\ldots,n+1 \quad (6)$$

(f) Add one to l and go back to step (d). Continue until the entire auxiliary matrix has been determined (i.e. until l=n).

THE SOLUTION MATRIX

The solution matrix is a column matrix whose elements are $x_1, x_2, x_3, \ldots, x_n$. The elements are computed in reverse order; in other words, x_n is computed first, x_{n-1} is computed second, x_{n-2} third, etc. The elements of the solution matrix are obtained from the auxiliary matrix by

$$x_i = b_{i,n+1} - \sum_{k=i+1}^{n+1} x_k b_{ik}, \quad i=n,n-1,\ldots,2,1$$

As an example, consider the following set of equations:

$$\begin{aligned} 2x_1 + 3x_2 + x_3 &= 7 \\ 8x_1 + 4x_2 + 6x_3 &= 11 \\ 9x_1 + 10x_2 + 5x_3 &= 12 \end{aligned}$$

The original matrix is

$$\begin{bmatrix} 2 & 3 & 1 & 7 \\ 8 & 4 & 6 & 11 \\ 9 & 10 & 5 & 12 \end{bmatrix}$$

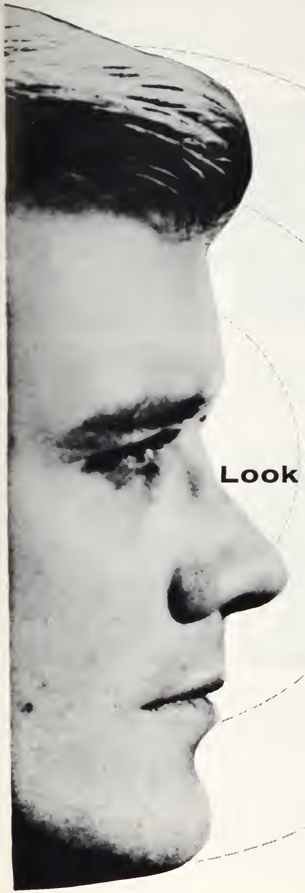
The auxiliary matrix is

$$\begin{bmatrix} 2 & 1.5 & 0.5 & 3.5 \\ 8 & -8 & -.25 & 2.125 \\ 9 & -3.5 & -.375 & 32.167 \end{bmatrix}$$

where some sample calculations are

b21 = 8
b14 = (7)/2 = 3.5
b32 = 10-9·1.5) = -3.5
b24 = 11-(8·3.5) /(-8) = 2.125
b33 = 5-(9·0.5+3.5·.25) = -.375
b34 = 12-(9·3.5=3.5·2.125) /(-.375) = 32.167

--Continued on page 30



First, what is the obvious? It's obvious that you're in demand. You don't have to worry about getting your material wants satisfied. And you don't have to worry about getting opportunities for professional growth.

But, if you look beyond the obvious, you'll realize now that you're going to want something more than material rewards from your career. You're going to want **pride**—pride in your personal, individual contribution.

Melpar is a proud Company. We're proud of our approach to the solution of problems; we're proud of our growth pattern; and we're proud of the communities that surround our laboratories and plants in Northern Virginia.

But most of all, we're proud of our contributions in the areas of basic and applied research, design, development and production in the areas of Advanced Electronics, Aerospace Systems, and the Physical and Life Sciences. Our projects have ranged from tiny microcircuits to computers the size of a basketball court. From synthesis of an insect's nervous system to a study of cometary tails. From production of thousands of high reliability circuit boards for the Minuteman Program to construction of a transmitting antenna atop the Empire State Building.

Look beyond the obvious . . .

Melpar's broad activities have created requirements for engineers and scientists with degrees in Electrical Engineering, Mechanical Engineering, Physics, Chemistry, Mathematics, and the Biological Sciences.

If you want an opportunity to be proud of your contribution and your Company, we're interested in hearing from you. Tell us about yourself. Either ask your Placement Director for more information, or write to our Professional Employment Supervisor. Tell him if you would like to hear from one of your college's graduates who is now progressing at Melpar.

MELPAR INC

A SUBSIDIARY OF WESTINGHOUSE AIR BRAKE COMPANY

3451 Arlington Boulevard, Falls Church, Virginia

In Historic Fairfax County

(10 miles from Washington, D. C.)

An Equal-Opportunity Employer

Edited by Martin Felker

WHAT'S NEW

NEW SPACE-AGE MATERIAL

A sheet of it will take 1400°F. without wilting. Pound for pound, it's nearly as strong as steel. It can be machined or molded. A piece only 1/32-inch thick will block an electrical surge of 45,000 volts. It's not measurably affected by a radiation attack nearly 2 million times stronger than would kill a man. The new G-E material, called inorganic bonded mica mat, is designed to be used anywhere from a space vehicle to a toaster.

Mica has long been used as an electrical and thermal insulator, of course, but it's impossible to obtain large enough pieces in nature to fabricate into uniform segments. GE's solution was to reconstruct the mica into wafer-thin sheets and laminate them to uniform thickness using an inorganic bonding material.

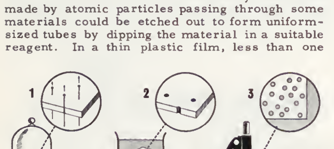
The bonding material has effectively added some 900 degrees to the temperature threshold of mica, giving 10BBM significant advantages over ceramics in the 500 to 1400 degree range. One advantage is weight: 10BBM has a specific gravity of only 2.1 compared to ceramics' 3 to 4. And sheets of mica laminate can be drilled, milled, sawed, punched, cut or filed with little or no waste.

Applications of this new material are limited only by the imagination of development engineers. Its unique combination of electrical and thermal properties makes it ideal for key structural components which are subject to severe environments.

CELL FILTER

A thin sheet of plastic containing superfine holes bored by atomic particles holds promise as an important new medical research tool. It may also prove useful in the early detection of some forms of cancer.

Research on fission fragment "tracks" in solid materials led to the discovery that holes made by atomic particles passing through some materials could be etched out to form uniform-sized tubes by dipping the material in a suitable reagent. In a thin plastic film, less than one thousandth of an inch thick, bombardment by fission fragments creates irregular holes a few atoms in diameter. Chemical etching converts the ragged holes into tubes of uniform size and roundness. Tube diameters ranging from one micron or less up to about ten microns have been achieved. The number of holes can be increased simply by longer irradiation.



Using the new filter, medical researchers have achieved the non-destructive filtration of free-floating cancer cells from blood. Such cells, often discovered in the blood of patients known to have cancer, usually are larger in size than normal cells found in blood.

On the basis of early experiments, the new plastic filter hopefully may prove to be a valuable diagnostic tool for the early detection of some forms of cancer -- for example, by filtering blood samples taken during medical examinations.

SUBMARINERS AND SPACEMEN BREATHE EASIER

A whispy synthetic membrane, only a thousandth of an inch thick, may soon bring to reality man's age-old wish to "breathe" under water like a fish. It may also hold the answer to a simple system for supplying submarines with air drawn from the surrounding sea, the purification of air in space capsules or moon stations, and a means of providing cheap reliable oxygen supplies for patients in hospitals or at home.

General Electric's Research Laboratory developed a method of producing a very thin, hole-free, yet permeable, silicone film that permits the passage of gases and liquids in both directions. The key to its usefulness is its "selectivity" or ability to let gases pass through at different rates.

--Continued on page 30

OPERATIONS RESEARCH—from page 19

Many operations are affected by influences beyond the limits of OR techniques. The analyst will often point these out in his report, but it is the executive's responsibility to use his own experience and judgment in evaluating them -- and then to decide on the course of action.

PERSONAL REQUIREMENTS

The practice of Operations Research, like that of many other professions, is usually facilitated by advanced education. Recently, the Education Committee of the Operations Research Society of America listed the principal requirements as competence in: mathematics, with particular emphasis on probability and statistics; theoretical methods of OR and problem formulation; application of theory to practical problems.

OR demands the same qualities needed by any competent scientist -- and something more. The OR analyst needs not only a basic desire to investigate; he must also be willing and able to explore unfamiliar situations for which little theoretical information is available.

OR is not "ivory tower" research. It deals with practical problems of real-world operations. This places several demands on the analyst. While aiming at accuracy, he must often work with limited or imprecise data. He may have too few opportunities to gather experimental data. Instead, he may have to show initiative, ingenuity, and tact to get the information he needs; and he must be willing to leave his desk for the field when necessary. OR professionals take pride in imaginative or even unorthodox answers to problems. But the analyst must be able to distinguish between an approach which is merely theoretically possible and one which is practical.

To obtain information and to convey research results, the analyst must be able to explain his work in terms that non-scientists will understand. He must also be able to communicate with scientists from other disciplines and to work with them on interdisciplinary teams.

The OR analyst may have to challenge an organization's traditional methods and managers' opinions about their objectives. For this, he needs courage. He may face resistance to the changes he recommends, so he requires persuasiveness and professional integrity to defend the findings of his research.

A CAREER WITH A FUTURE

OR has reached its present importance because executives have needed scientific help on major, complex problems. This need will continue to expand. There are several reasons:

Organizations are growing in size and complexity;

Many projects are increasing in size, cost, complexity, and in the time needed to complete them;

Executives are becoming familiar with OR and its potential for increasing the effectiveness of an operation and reducing its cost;

The ever increasing growth of technology is posing completely new problems to which OR techniques can be applied;

OR professionals are discovering new methods and techniques to solve a wider range of existing problems.

These trends have resulted in the creation of many organizations specializing entirely or in part in OR. Many major industries have established an OR capability in their own structure; others contract for the needed analyses. The military has largely sought support through continuing contracts, augmented by contracts for the solution of specific, more narrow problems. The Center for Naval Analyses of The Franklin Institute is but one of several similar groups which provide analytical studies for the Defense establishment.

OPERATIONS RESEARCH PROBLEM

Task Force Defense

In simplified form, this problem can be stated as:

"What spacing should be used by a given task force of carriers and escorts to reduce the probable damage from attack by an enemy force of submarines, aircraft, and missiles, assuming that the enemy may use nuclear weapons?"

Fairly close spacing is desirable to defend against submarine attack and to provide mutual anti-aircraft support. The possibility of nuclear attack, however, dictates that intervals between carriers be opened to minimize the potential damage by a single bomb.

One immediate effect of opening the intervals between carriers is that a fixed number of escorts must then protect against submarine attack over an expanded formation perimeter. Consideration of geometry and likely detection ranges will indicate that at some point is better to abandon the escort screen around the whole formation, and screen the heavy ships individually. One OR problem is to determine that point.

Mathematically, the problem becomes one of finding the optimum balance between mutually contradictory factors. Among the factors which the analyst must consider are the speed of the formation, the likely lethal radii of weapons used against it, and the expected numbers and capabilities of our defensive systems. The best possible spacing may be determined by graphically plotting the spacing needed for submarine defense against that needed to minimize nuclear damage. The number of escorts for a given expected level of defense may also be determined from the analysis.

Fleet exercises are often used to provide data needed for such an analysis and to confirm the validity of the study results.

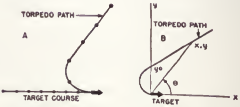


Figure 1. Typical tractrix. (A) In true space. (B) In relative space.

APPLICATION OF VOCODERS—from page 23

gain, and sensitive receivers to scatter and recover enough energy from the E region of the ionosphere to carry on highly reliable communications over path lengths of from 1000 to 2000 kilometers. Because of the relative inefficiency of the propagation mechanism, ionoscatter paths are not normally troubled by multipath propagation of the type experienced on h.f. radio circuits. However, meteorites entering the earth's atmosphere are normally incinerated in the E region of the ionosphere, producing columns of highly ionized gases. These columns act as efficient reflectors of EM energy and may persist for several seconds. Properly oriented columns located off the great circle path between two ionoscatter communications stations frequently produce multipath delays of 100 microseconds or more. Delays of 100 microseconds in themselves will not produce errors in a 2400 baud signal; however, when these delays are added to the fortuitous distortion produced by noise in the communications channel, some errors will undoubtedly result. The ability of the vocoder to tolerate a relatively high bit error rate will permit the equipment to operate satisfactorily in the presence of this multipath mode.

Vocoders appear to be gaining increased recognition by military users. Their popularity stems from their ability to provide security and to simultaneously improve the audio signal to noise ratio of a voice communications channel. Recent models provide reasonable speaker recognition, which is also considered important by military users. These advantages should assure the vocoder a sound future in military communications systems.

SOLVING SYSTEMS—from page 24

And, the solution matrix is

$$\begin{bmatrix} -27.8333 \\ 10.1667 \\ 32.1667 \end{bmatrix}$$

where the calculations are

$x_3 = 32.1667$
$x_2 = 2.125+(32.167x.25) = 10.1667$
$x_1 = 3.5-(10.167x1.5+32.167x0.5) = -27.8333$

Substitution of these values into the original equations will verify that they satisfy all three equations.

APPLICATIONS

This method is especially adapted for use with desk calculators or automatic computers. In the latter case, it should be noted that once a term is calculated for the auxiliary matrix, its corresponding term in the original matrix is never referred to again, so that one may find the auxiliary matrix simply by replacing each term of the original matrix by the newly computed term.

It should also be noted that for systems with symmetrical coefficients, the work is further reduced, since the row equation, eq. (6), becomes

$$b_{1j}=b_{j1}/b_{11} \tag{7}$$

The rules presented here represent only the fundamental procedures of the Crout method. These principles may be modified and extended to include (1) evaluation of determinants, (2) solution of n x m systems, (3) systems with complex coefficients, and (4) the addition of a check column which provides a continuous check of calculations while finding the auxiliary matrix.

For details on the above, and for a proof of the method, the reader is referred to the original article:

"A Short Method for Evaluating Determinants and Solving Systems of Linear Equations with Real or Complex Coefficients"

—by PRESCOTT D. CROUT

A.I.E.E. Transactions, 1941, Vol. 60, pp. 1235-1241.

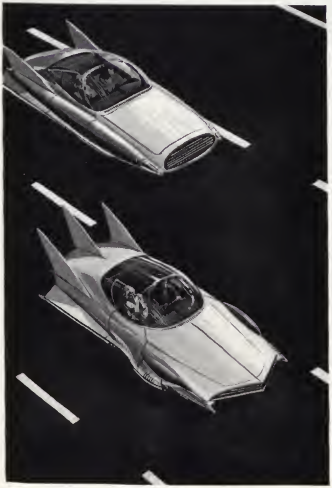
WHAT'S NEW—from page 26

In underwater applications, a membrane with sea water on one side and with pressure below one atmosphere on the other side will extract air from the water while resisting the passage of water under great pressure. Carbon dioxide and other noxious gases will pass through the membrane in the reverse direction, into the water. Thus the membrane can perform the same function as a gill in a fish. As an added bonus for the crew of an underwater vehicle or station, the small quantity of water passing through the membrane would be desalinated and completely potable.

In the vacuum of space, a vehicle or station could have an opening covered with such a membrane which would allow unwanted water vapor and carbon dioxide to escape while holding in vital oxygen because the first two gases pass through much more quickly than oxygen.

Oxygen, on the other hand, passes through a silicone membrane twice as fast as nitrogen, which comprises nearly 80% of our air. Thus in a low-pressure enclosure with some membrane surfaces, oxygen from the outside air would enrich the air inside. At 1/15 atmospheric pressure, for example, the air passing through will contain about 35% oxygen — a figure close to that of hospital oxygen tents and infant incubators.

INDEX TO ADVERTISERS



THE SHAFT

A Freshman Engineer called home after his first semester: "Mother, you told me the stork brought me."

"Yes, dear."

"I weighed 8 pounds, you said."

"Yes, dear."

"I have news for you, Mother. A stork's wing spread, according to my calculations of lift and drag, is insufficient to carry an eight pound load."

* * *

Definition of College Years: the only vacation a boy gets between his mother and his wife.

* * *

A clergyman and a truck driver found themselves in an automobile smashup. The truck driver told the minister what he thought of him in profane terms. When he paused for breath, it was the clergyman's turn.

"You know, my good man, that I cannot indulge in your kind of language, but this much I will tell you; I hope when you go home tonight, your mother runs out from under the porch and bites you."

* * *

Of all the remedies that won't cure a cold, whiskey is the most popular.

* * *

Father (to son): "I'm sick and tired of arguing with you over borrowing the car. The next time I want it, I'm just going to take it."

* * *

History credits Adam and Eve with being the first bookkeepers, because they invented the loose-leaf system.

* * *

I walked into the barbershop,
The sign was very queer,
"During alterations
We will shave you in the rear."

* * *

A sign in a local store read as follows: "Our lingerie is the finest. Smart women wear nothing else."

Notice on student union menu: "T-BONE 25¢ (with meat $3.50)."

* * *

He'd shown her his etchings, and just about everything else in his apartment and, as Jack poured the last of the martinis into their glasses, he realized the moment of truth with Louise had arrived. He decided on the direct verbal attack.

"Tell me," he said smoothly, fingering a lock of her hair, "do you object to making love?"

She turned her lovely eyes up to his. "That's something I've never done," she said.

"Never made love?" cried Jack, appalled at the waste of magnificent raw material.

"No, silly," she answered in soft rebuke. "Never objected."

* * *

Three old men were discussing the ideal way to die. The first, aged 75, wanted to crash in a car doing 95 mph. The second, aged 85, wished to end it all in a jet plane doing 600 mph. The third, aged 95, said he had the ideal death, "I'd like to be shot by a jealous husband."

* * *

You never can tell about women, and if you can, you shouldn't.

* * *

One day during a war, a tall, strong, handsome Roman soldier broke into a house where he found two luscious maidens and their matronly nurse.

Chuckling with glee, he roared, "Prepare thyselves for a conquest, my pretties."

The lovely girls fell on their knees and pleaded with him, "Do with us as thou wilt, O Roman, but spare our faithful old nurse."

"Shut thy mouth," snapped the nurse. "War is war."

* * *

E.E.: "She's a nicely reared girl, isn't she?"

M.E.: "Not bad from the front either."

A number of showgirls were entertaining the troops at a remote Army camp. They had been at it all afternoon and were not only tired but very hungry. Finally at the close of their performance the major asked, "Would you girls like to mess with the enlisted men or the officers this evening?"

"It really doesn't make any difference," spoke up a shapely blond. "But we've just got to have something to eat first."

* * *

A preacher recently announced that there are 735 sins.

He is being besieged with requests for the list, mostly from college students who think they're missing something.

* * *

OHM ON THE RANGE

Opus 204 in Three Phase Time

Oh, give me an ohm
Where the impedances roam
Where the fields are not fluxing all day
Where you'll never see
A field without phi,
And the flux is not leaking away.

Ohm, ohm on the range,
Where the flux is not changing all day.
Where never is seen
A shunt field machine
With the armature running away.

* * *

Overheard at a Fraternity party: "I'm bushed. I think I'll flirt with some good-looking dame so my steady will take me home."

Should You Work for a Big Company?

An interview with General Electric's S. W. Corbin, Vice President and General Manager, Industrial Sales Division.

S. W. CORBIN

■ Wells Corbin heads what is probably the world's largest industrial sales organization, employing more than 8000 persons and selling hundreds of thousands of diverse products. He joined General Electric in 1930 as a student engineer after graduation from Union College with a BSEE. After moving through several assignments in industrial engineering and sales management, he assumed his present position in 1960. He was elected a General Electric vice president in 1963.

Q. Mr. Corbin, why should I work for a big company? Are there some special advantages?

A. Just for a minute, consider what the scope of product mix often found in a big company means to you. A broad range of products and services gives you a variety of starting places now. It widens tremendously your opportunity for growth. Engineers and scientists at General Electric research, design, manufacture and sell thousands of products from microminiature electronic components and computer-controlled steel-mill systems for industry; to the world's largest turbine-generators for utilities; to radios, TV sets and appliances for consumers; to satellites and other complex systems for aerospace and defense.

Q. How about attaining positions of responsibility?

A. How much responsibility do you want? If you'd like to contribute to the design of tomorrow's atomic reactors—or work on the installation of complex industrial systems—or take part in supervising the manufacture of exotic machine-tool controls—or design new hardware or software for G-E computers—or direct a million dollars in annual sales through distributors—you can do it, in a big company like General Electric, if you show you have the ability. There's no limit to responsibility . . . except your own talent and desire.

Q. Can big companies offer advantages in training and career development programs?

A. Yes. We employ large numbers of people each year so we can often set up specialized training programs that are hard to duplicate elsewhere. Our Technical Marketing Program, for example, has specialized assignments both for initial training and career development that vary depending on whether you want a future in sales, application engineering or installation and service engineering. In the Manufacturing Program, assignments are given in manufacturing engineering, factory supervision, quality control, materials management or plant engineering. Other specialized programs exist, like the Product Engineering Program for you prospective creative design engineers, and the highly selective Research Training Program.

Q. Doesn't that mean there will be more competition for the top jobs?

A. You'll always find competition for a good job, no matter where you go! But in a company like G.E. where there are 150 product operations, with broad research and sales organizations to back them up, you'll have less chance for your ambition to be stalemated. Why? Simply because there are more top jobs to compete for.

Q. How can a big company help me fight technological obsolescence?

A. Wherever you are in General Electric, you'll be helping create a rapid pace of product development to serve highly competitive markets. As a member of the G-E team, you'll be on the leading edge of the wave of advancement—by adapting new research findings to product designs, by keeping your customers informed of new product developments that can improve or even revolutionize their operations, and by developing new machines, processes and methods to manufacture these new products. And there will be classwork too. There's too much to be done to let you get out of date!

FOR MORE INFORMATION on careers for engineers and scientists at General Electric, write Personalized Career Planning, General Electric, Section 699-12, Schenectady, N. Y. 12305

GENERAL ELECTRIC

An Equal Opportunity Employer